VACUUM ULTRAVIOLET EMISSION AND ABSORPTION PROPERTIES OF GASES AND HOT PLASMAS

Masaru Ogawa, et al

University of Southern California

Prepared for:

Office of Naval Research

15 September 1974

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: USC-Internal USC Report No.:VacUV-150
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER: AD-787461

4. TITLE *(and Subtitle)*: VACUUM ULTRAVIOLET EMISSION AND ABSORPTION PROPERTIES OF GASES AND HOT PLASMAS

5. TYPE OF REPORT & PERIOD COVERED: Final Report for period from 16 June 1964 to 30 June 1974

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s):
G.L. Weissler, Principal Investigator, and
M. Ogawa, Co-Investigator, Professors of Physics
Tel: (213) 746-2792

8. CONTRACT OR GRANT NUMBER(s): N00014-67-A-0269-0014

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
University of Southern California Code 01B729
University Park
Los Angeles, CA 90007

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Program Element 121109
ARPA Order No. 125-62

11. CONTROLLING OFFICE NAME AND ADDRESS:
Office of Naval Research, Pasadena Branch Office
1030 East Green Street
Pasadena, CA 91106

12. REPORT DATE: 15 September 1974

13. NUMBER OF PAGES: 21 pages

14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*:
as in 11. above

15. SECURITY CLASS. *(of this report)*: unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: does not apply

16. DISTRIBUTION STATEMENT *(of this Report)*:
The distribution of this report is now limited to those listed in V. Distribution List. Otherwise unlimited if requested as long as supplies last.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*:
does not apply

18. SUPPLEMENTARY NOTES:
The references marked with a double arrow (⟹) in the Appendix A refer to publications and Tech. Reports on research sponsored under this contract.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*:
Vacuum ultraviolet radiation, soft X-rays spectroscopy, plasma, photoionization, photoabsorption, photodissociation, cross section, band analysis, fluorescence, light sources.

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*:
This report summarizes research done by G.L.Weissler and M.Ogawa, together with their associates and students at USC, during the period from 16 June 1967 to 30 June 1974 on "Vacuum Ultraviolet Emission and Absorption Properties of Gases and Hot Plasmas." Names of participating personnel and titles of published papers and reports have been provided.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

Internal USC Report No.: USC-VacUV-150

Final Technical Report

issued

15 September 1974

on ONR Contract No.: N00014-67-A-0269-0014

Sponsored by Advanced Projects Agency, No. 125-62

on research done during the 10-year period ending 30 June 74

on the general topic of

VACUUM ULTRAVIOLET EMISSION AND ABSORPTION PROPERTIES OF GASES AND HOT PLASMAS

by

Masaru Ogawa and G. L. Weissler
Co-Investigator and Principal Invest.

at the

Department of Physics, USC, Los Angeles 90007

prepared for

The Department of the Navy
Office of Naval Research, Code 421
Washington, D.C.

ia

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

VACUUM ULTRAVIOLET EMISSION AND ABSORPTION PROPERTIES

OF GASES AND HOT PLASMAS

Table of Contents

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Office of Naval Research under Contract No. N00014-67-A-0269-0014.

I. INTRODUCTION

AND GENERAL AIMS OF RESEARCH

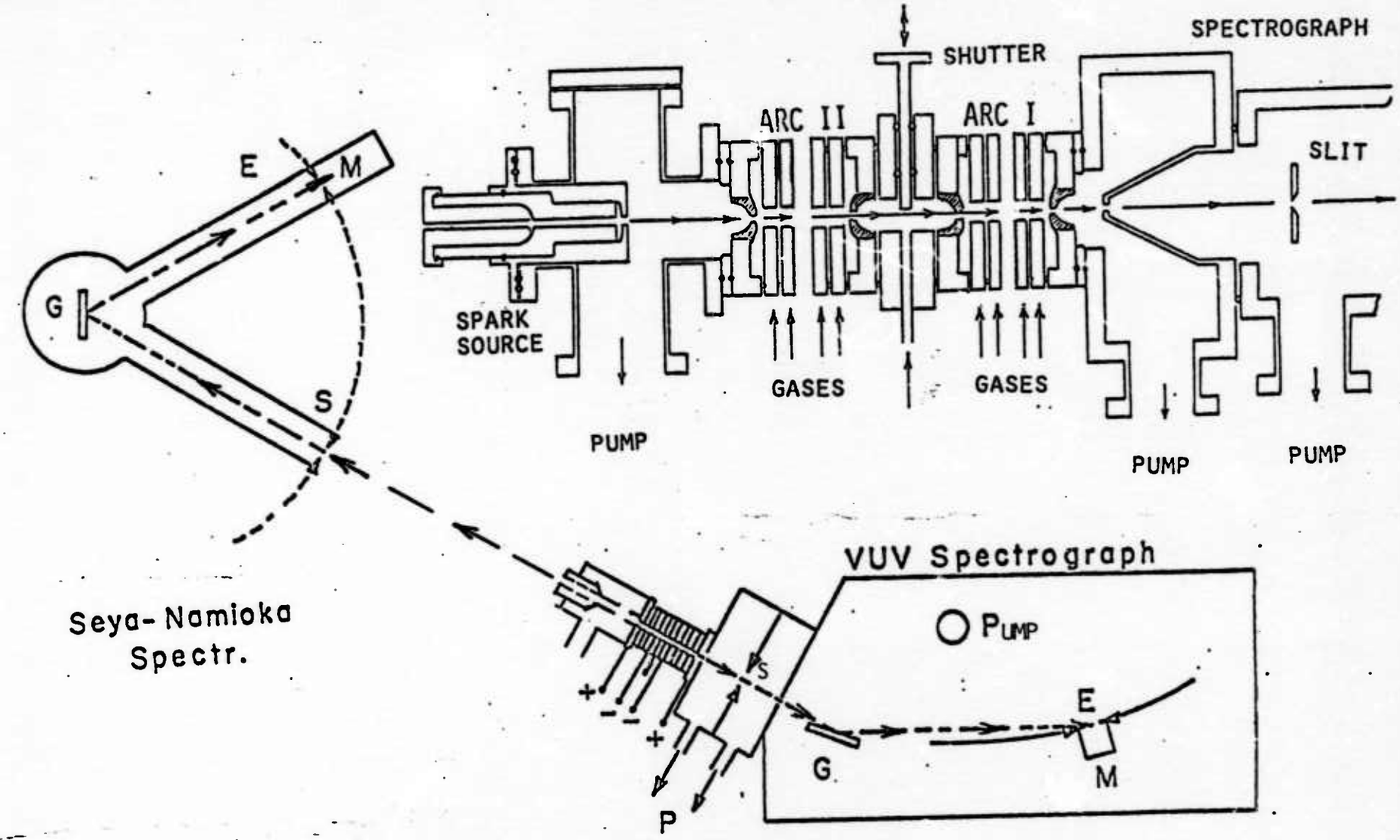
Various aspects of the interaction of vacuum ultraviolet (vuv) radiation with matter, either gaseous or solid or both, have been supported by ONR at this university since 1947. As a consequence of this continuing funding, even though modest in each annual amount, an active and expanding research group developed at USC, which comprises three tenured professorships (D. L. Judge, M. Ogawa, and G. L. Weissler) and a non-tenured assistant professorship to be filled in the near future with a theorist competent in this general area of atomic and molecular physics.

While the activities of the three principals mentioned above are best described in terms of their respective publication lists, which are on file with the Physics Division of ONR as part of various contract proposals and which can always be supplied upon request, never-the-less a brief statement describing their activities may be in order. It should of course be realized that due to close proximity and colaboration, there may be considerable overlapping.

Dr.D. L. Judge, Assoc. Prof. of Physics, is conducting research in three different locations: in v.u.v. laboratories at USC, at the Synchrotron v.u.v. Radiation Facility of the Univ. of Wisconsin, Madison, Wisconsin, and with flight experiments in rockets, probing the earth's atmosphere, and in Jupiter-fly-by planetary probes, Pioneer 10 and 11, probing the neighborhood of that planet. As many as 5 or 6 post-doctoral fellows, and several graduate and undergraduate students assist Dr. Judge in these efforts.

Dr. Masaru Ogawa, Prof. of Physics, is devoting his principal effort towards v.u.v. spectroscopy in his laboratories at USC. His research problems can be grouped logically into two areas: first, the analysis of absorption spectra of simple molecules, i.e. O_2, CO, CO_2, etc., and second, the accurate measurement of specific of absorption cross sections of both atomic and molecular gases. His choice as to which gases are to be investigated is dictated by the need-to-know in planetary atmospheric physics and chemistry problems and by a general effort to supply new and improved atomic and molecular data. Prof. M. Ogawa is assisted in this by his wife, adjunct professor of physics and 2 or 3 graduate students. In addition, Dr. M. Ogawa is actively involved with Dr. D. L. Judge in designing and performing v u.v. experiments on the interaction of radiation with gases, using the Synchrotron radiation at Madison, Wisconsin.

Prof. G. L. Weissler has directed his major research efforts in recent years towards v.u.v. and visible region spectroscopy of hot, gaseous plasmas, as produced in high-pressure (1 atm.), high-temperature (10,000 to 25,000°K), wall-stabilized high-current (100 or more amperes) arcs. The general type of experimental arrangement is shown in the accompanying figure. There, two plasma arcs in tandem have their axes aligned with the optical axes of both a grazing indicence vacuum spectrograph (operating between 100 Å and 3000 Å) and a Seya-Namioka spectrograph (operating primarily in the visible region). The plasma properties of these arcs and their plasma constituents, either atoms or ions, can be studied by both instruments either in emission (using the well-known plasma equations pertaining to cases of local thermal equilibrium or LTE) or in absorption, in which case a spark light source external to the arcs shines light in the v.u.v. region through the arc(s), and the



Experimental arrangement for transmission and emission measurements with arc plasmas; using a 2m grazing incidence vacuum uv spectrograph (lower right) and a Seya-Namioka spectrograph (upper left). The inset (upper right) shows details of the double arc system together with the low pressure capillary spark source . S, E, and M refer to primary slit, exit slit, and photomultiplier, respectively.

absorption cross section of atomic and ionic plasma constituents can be measured directly, since number densities can be obtained if LTE prevails.

More details on the research efforts of both Drs. Ogawa and Weissler can be gleaned from their respective lists of papers, published under auspices of ONR (as indicated by an arrow: $\Longrightarrow$), which have been made part of this report in terms of Appendix A.

In addition, a list of students who worked on ONR-supported research during the last 10 years is given in Appendix B.

II. SCIENTIFIC AND TECHNOLOGICAL SIGNIFICANCE OF RESEARCH

It has been pointed out in earlier Extension Proposals that all the gases investigated here play a significant role in literally hundreds of significant atmospheric reactions. (See for instance: Adolf R. Hochstim, "Bibliography of Chemical Kinetics and Collision Processes"; IFI/Plenum, New York 1969.) It need not be further emphasized, how the research on absorption cross sections, on spectroscopic term analysis of vibrational and rotational structure, on the classification of many to date unknown absorption bands, series and progressions, of necessity will contribute in a most serious manner to our better understanding of many atmospheric processes, particularly the role of either vibrationally or electronically excited species (or both) in certain collision processes with significant rate constants.

The laboratory studies undertaken here, provide detailed information on electronic molecular energy levels, their identification, spacing, associated vibrational and rotational constants, and to a limited extent, educated guesses as to the relative transition probabilities from relative band strengths. All of this basic molecular physics information must be considered a prerequisite for the more complex studies of atmospheric collision processes.

In addition, the arc plasma spectroscopy measurements of f-values of emission lines and of photoionization cross sections of atoms and atomic

ions will contribute to our understanding of the various physical processes involved in rocket plumes, hot gaseous core reactors, astrophysical plasmas and similar phenomena involving the interaction of radiation with hot gases.

ACKNOWLEDGEMENT

The continued support of both ONR and ARPA is hereby gratefully acknowledged.

(signed): G. L. Weissler
Principal Investigator

(signed): Masaru Ogawa
Co-Investigator

III. APPENDIX A

PUBLICATIONS AND TECH. REPORTS ON RESEARCH SPONSORED BY ONR CONTRACT, 1964-1974.

The following pages are excerpts from the Publication Lists of Prof. G. L. Weissler (pages 6 to 10) and Prof. Masaru Ogawa (pages 2 to 4), both at USC and working jointly.

Research problems supported wholly or in part by ONR have been marked with a double arrow, thus: $\Longrightarrow$. Presentations of research reports at APS-meetings, Annual Gaseous Electronics Conferences, Annual Meetings of the APS Division of Electron and Atomic Physics, and similar national and regional conferences on the whole (but not always) have been excluded here. Suffice it to say here, that on the average say at least two such conference contributions per year have been made.

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IV. APPENDIX B

STUDENTS, POST-DOCTORAL FELLOWS, AND VISITING PROFESSORS

SUPPORTED BY ONR

G. S. Bloom, undergrad. and later grad. student; 65-67.

R. S. Barak, undergrad. student; 65.

H. E. Blackwell, grad. stud. 64-68, M.S. and Ph.D. at USC, now Prof. of Physics at Texas Southern Univ., Houston.

H. C. Chang, grad. stud. 66-71, Ph.D. at USC, now in industry in the Los Angeles Metropolitan Area.

Scott Daubin, Jr., undergrad. and grad. stud. 70-71, M.S. at USC, now Ph.D.-candidate in Physical Oceanography at the Lamont Geophysical Lab. of Columbia Univ.

S. Furmanski, undergrad. 64-65. now Stanford Ph.D.

D. L. Judge, grad stud. and post-doctoral 64-68, M.S. and Ph.D. at USC, now Assoc. Prof. of Physics at USC.

T. R. Knowles, undergrad. at USC 69, now Ph.D. candidate at U.C. San Diego.

Atsuo Matsui, Post-doctoral 69-70, now Assoc Prof. of Physics at Konan Univ., Kobe, Japan.

A. L. Morse, grad. stud. 62-66, M.S. and Ph.D. at USC, now Consultant in L.A. Metropolitan Area.

J. R. Hyde, grad stud. 66.

C. W. Patterson, undergrad. stud. 67-68, M.S. and Ph.D. at USC in Theoretical Physics (not G.L.W. or M.O.) 1974.

E. Rudisill, grad. stud., 68-70, M.S. and Ph.D. at USC, now at Hughes Res. Lab., Malibu.

S. K. Srivastava, grad. stud. 70-72, M.S. and Ph.D. at USC, now at Jet Prop. Lab., Pasadena.

M. Whitson, grad. stud., 67-69, M.S. at USC,

W. Hofmann, post-doctoral, 69-70, now in Munich.

R. A. Vangor, undergrad. stud., 68.

Students, Post-Doctoral Fellows, and Visiting Professors supported by ONR (cont'd.)

R. K. Yamawaki, grad. stud., 68-71, M.S. and Ph.D. at USC, now employed in L.A. Metropolitan Area.

N. Wainfan, visiting professor 68-69 (former stud. of G.L.W.), now Prof. of Physics, Brooklyn Polytech.

C. R. Whalley, undergrad. and grad. stud., 69-70, now Ph.D.-candidate at University of Illinois.

H.-H. Carls, post-doctoral, Nato-Fellowship 73-74, from University of Kiel, Germany.